Management by Constraints: Considering Patient Volume when Adding Medical Staff to the Emergency Department

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Key words: emergency department, length of stay, patient volume, management by constraints

Abstract

Background: The emergency department is one of the hospital's busiest facilities and is frequently described as a bottleneck. Management by constraint is a managerial methodology that helps to focus on the most critical issues by identifying such bottlenecks. Based on this theory, the benefit of adding medical staff may depend on whether or not physician availability is the bottleneck in the system.

Objective: To formulate a dynamic statistical model to forecast the need for allocating additional medical staff to improve the efficacy of work in the emergency department, taking into account patient volume.

Methods: The daily number of non-trauma admissions to the general ED was assessed for the period 1 January 1992 to 1 December 1995 using the hospital computerized database. The marginal benefit to shortening patient length of stay in the ED by adding a physician during the evening shift was examined for different patient volumes. Data were analyzed with the SAS software package using a Gross Linear Model.

Results: The addition of a physician to the ED staff from noon to midnight significantly shortened patient LOS: an average decrease of 6.61 minutes for 80–119 admissions ($P < 0.001$). However, for less than 80 or more than 120 admissions, adding a physician did not have a significant effect on LOS in the ED.

Conclusions: The dynamic model formulated in this study shows that patient volume determines the effectiveness of investing manpower in the ED. Identifying bottleneck critical factors, as suggested by the theory of constraints, may be useful for planning and coordinating emergency services that operate under stressful and unpredictable conditions. Consideration of patient volume may also provide ED managers with a logical basis for staffing and resource allocation.

IMAJ 2002;4:170–173

Human resources are the single most expensive element in healthcare costs, accounting for a large proportion of the national expenditure on health in the United States. In Israel, human resources were responsible for 75% of the national expenditure on health in 1993 [1]. One of the greatest concerns of health service managers is how to invest manpower efficiently to achieve maximal benefit for a given input.

The emergency department is one of the busiest and most overcrowded facilities within the hospital and is frequently described as a bottleneck [2]. Patient referrals to public emergency departments in the USA have been increasing steadily since the 1980s, resulting in growing ED congestion [3,4]. A similar trend was observed in Israel [5]. Various formulas have been proposed for physician staffing in the ED [6,7]. However, since formulas do not take into consideration patient case-mix and acuity, there is no one single formula that is accepted widely.

The goal of the ED is rapid patient assessment, stabilization, and prompt admission to the hospital – or discharge – upon a medical decision. However, the reality is frequently different. Some studies have found that prolonged length of stay in the ED is related to hospital-bed availability, the registration process, and use of special procedures such as computerized tomography [8,9].

Various studies have examined patient flow in the ED by directly measuring service times [9] and their relation to physician performance [10]. These studies defined variables affecting the length of patient visits, such as laboratory tests and consultations. However, these factors are time consuming and reflect the situation only at a given point in time.

Management by constraint is a global managerial methodology that helps the manager to focus on the most critical issues [11]. It identifies the institute's bottlenecks and inner conflicts [12]. Based on this theory, the benefit of adding medical staff may depend on whether or not physician availability is the bottleneck in the system.

We defined volume of patient admissions to the ED in a given time range as the independent variable that reflects the ED workload. Our study hypothesis was that the rate of admissions to the ED has an effect on the individual length of stay: i.e., patients admitted during a busy shift will stay longer in the ED. Our hypothesis proposes that for low patient volumes, physician availability is not the limiting factor; whereas at high patient volumes other bottleneck factors, such as nursing staff administration and laboratories, determine ED efficacy.

Our study was conducted to examine whether the management by constraint theory is applicable to emergency departments, and to test the applicability of patient flow in the ED as an index (a parameter) of workload.

Methods

The study group comprised all non-trauma patients admitted to a large 24 hour-based ED in a university-affiliated tertiary public medical center during the period 1 January 1992 to 31 December 1995.

An administrative change was carried out in two stages: first, an additional physician was put on duty during the evening shift (16:00–24:00) on Sundays only (stage I: 1 October 1993 to 31 March

ED = emergency department
LOS = length of stay

1995). On Sundays (the first working day following the 2 day weekend in Israel) the large EDs are especially crowded, with an excess of 26% over the average number of daily visits, regardless of the season of the year (x). Following the first 6 months (stage I), an additional physician was put on duty for the same shift, on all week days (including Sundays) (stage II: 1 April 1995 to 1 December 1995)..

Statistical analysis

Data were extracted from the computerized ED information system, which contains individual data on patient flow in the ED as well as staffing parameters.

a) Patient LOS in the ED during the evening shift was examined before and during stage I and stage II of the administrative change.
b) The marginal benefit of an additional physician to shortening patient LOS was examined for different patient volumes in the ED, irrespective of their diagnosis on admission or discharge.
c) In order to exclude other parameters that could have caused a change in the outcome measurements (such as a change in patient case-mix, or climate conditions), the above parameters were also examined for the morning shift (08:00–16:00) in which no staffing changes were made during the study period. Thus, patients admitted during the morning shift served as a control group.

The ANOVA (analysis of variance) model was used for data analysis. The Gross Linear Model (GLM) procedure of the SAS software package was used for analysis [13]. Outcome measurements were defined as follows:

LOS was defined for the different staffing stages (P) and patient volumes (S).

a) $P = 0$ is a period during which there were N physicians on the evening shifts: These physicians were included on all weekdays during the period 1 January to 30 September 1993, and Mondays to Thursdays during 1 October 1993 to 31 March 1995.
b) $P = 1$ is a period with $N + 1$ physicians in the evening shifts: on Sundays from 1 October 1993 to 31 March 1995 and all weekdays from 1 April to 31 December 1995.

Since the administrative change was applied to the evening shift only, LOS was measured for patients who were both admitted to and discharged from the ED between 16:00 and 24:00 (i.e., the evening shift).

S was defined as the total number of patients admitted to the ED between 12:00 and 24:00. The average LOS for patients arriving between 12:00 and 16:00 was slightly more than 3 hours; we therefore considered patients admitted up to 4 hours prior to the beginning of the evening shift to have an effect on ED crowding during the evening shift. For the morning shift, variable S was defined as the volume of admissions between 04:00 and 16:00 (assuming that patients admitted to the ED up to 4 hours prior to the beginning of the morning shift may contribute to its crowding). The total number of admission during the evening shift (S) was grouped by increments of 10: 50–59, 60–69, etc. The ANOVA model was then defined as LOS = (P,S). F test was used to examine the null (Ho) hypothesis that states: $(P = 0,S) - (P = 1,S) = 0$. This was examined for each S group.

Results

The null hypothesis, stating that no difference exists between the period with N physicians and the period with $N + 1$ physicians, was rejected ($F = 10.77$, $P < 0.01$). The calculated difference may be an underestimation of the actual difference, since the trend towards progressive increase in volume of admissions to the ED was not taken into account.

Table 1 examines the effect of an additional physician on LOS, for different S values. It is evident that for an average of 80 admissions to the ED during the hours 12:00 to 24:00, the addition of a physician to the previous (N) number of physicians is not effective as there was practically no significant change in LOS. In the range of 80–119 admissions, the addition of a physician significantly shortened patient LOS: an average decrease of 6.61 minutes ($P<0.001$). Above 120 admissions, adding a physician did not have any significant effect.

Patient length of stay during the morning shift did not change significantly between the two periods (before and after the administrative changes). This finding was consistent for all categories of patient volume in the ED [Table 2]. Alternatively, shortened LOS could be demonstrated by comparing the proportion of patients in each LOS category (0–90, 91–180, > 180 minutes)

Table 1. The marginal contribution by patient volume of an additional physician to shortening patient length of stay in the emergency department

No. of admissions	Estimate*	SE of the estimate	T	*P*	Ho hypothesis
50–59	–9.7	8.95	–1.08	NS**	Accepted
60–69	5.93	4.87	1.22	NS	Accepted
70–79	–0.81	3.5	0.23	NS	Accepted
80–89	–6.24	1.92	3.25	0.0011	Rejected
90–99	–3.54	1.66	–2.13	0.033	Rejected
100–109	–11.78	1.89	–6.21	0.0001	Rejected
110–119	–9.72	6.17	–1.55	0.0004	Rejected
⩾120	–9.73	6.17	–1.55	NS	Accepted

* $(P=0,S) - (P=1,S) = 0$

NS = not significant ($P>0.05$)

Table 2. The influence of adding a physician on patient length of stay in the emergency department

	Patient length of stay (minutes)			
Administrative change	**0–90**	**91–180**	**>180**	**Total**
Before				
No.	15,230	14,807	11,203	41,240
(%)	(36.9)	(35.9)	(27.2)	(72.5)
After				
No	5,719	5,967	3,935	15,621
(%)	(36.6)	(38.2)	(25.2)	(27.5)

$P<0.001$

before and after the administrative change [Table 2]. No influence was noted on short LOS (0–90 minutes). The proportion of patients spending 91–180 minutes in the ED increased from 35.9 to 38.2, while fewer patients spent more than 180 minutes (25.2% compared with 27.2%, $P<0.001$).

Discussion

The non-trauma (internal medicine) wing of the emergency department at the Sheba Medical Center, which is one of the busiest in the country, delivers medical care to an average of 160 patients a day, 52% of whom arrive during the evening shift. The growing pressure on emergency departments in Israel [1,3], including that at Sheba Medical Center [14], resulted in congestion (overcrowding) and increased patient LOS in the ED – from an average of 129 minutes in 1991 to 142 minutes in 1993. This consequently led to increased patient dissatisfaction.

Staff pressure to alleviate the ED congestion resulted in a decision, based on the management by constraint theory, to add a physician to the evening shift, assuming that this will resolve the presumed bottleneck factor. The present study examined the effect of this administrative change on patient LOS in the ED. We used a dynamic statistical model to study the theoretical impact of adding a physician for various ED patient volumes.

The administrative change led to an increase in the proportion of patients staying 90–180 minutes while decreasing the proportion of patients staying longer periods. The proportion of patients staying for shorter periods did not change, probably because of the "service floor," i.e., the minimal period required for basic procedures (administrative, nursing, laboratory, and imaging) that every patient admitted to the ED routinely undergoes, according to the ED protocol. For example, additional medical staff has a limited influence on hastening the completion of forms or the measurement of vital signs.

The core idea in the theory of constraints is that all systems have at least one major constraint. Because a constraint is a factor that limits the system from getting more of whatever it strives for, we have to manage the constraint [15]. Work in the ED can be viewed as a linked sequence of processes that transform inputs (undiagnosed patients) into outputs (diagnosed, treated patients). According to the theory of constraints, improving the process relies on a concentrated effort to strengthen the weakest link. This demands identifying the slowest unit in the process, which sets the pace for the entire process, and intensifying the efforts toward this weakest link. The sequential process focuses on resources that will provide the greatest benefit. In a basic blueprint for continuing improvement, system resources are targeted at the point where they are likely to be most effective.

We identified physician shortage as an apparent constraint in the ED. We therefore attempted to define the optimal patient volumes that allow the greatest benefit from an additional physician. Our model indicates that these volumes represent intermediate crowding. It is suggested that for smaller patient volumes the human resources are not the rate-limiting factor. Instead, the basic routine requires a definite amount of time that is not influenced by the size of the medical staff. In a highly congested ED with a high patient volume, the size of the medical staff again seems to have a limited beneficial effect on patient length of stay. It is possible that the size of the nursing, auxiliary or administrative staff is insufficient to answer the growing needs, thus limiting the pace of the working process in the ED. Another explanation is that other units serving the ED, such as clinical laboratories and radiology, are too congested and constitute bottlenecks [2]. This hypothesis needs further investigation in order to isolate these parameters as explanatory variables for length of stay in the ED.

It would appear that any increase in the medical staff should shorten the patient LOS. However, the production function that relates the total product to variable inputs has a positive slope only when the marginal product is negative. The "law of diminishing marginal products" defines a level of input from which, although the variable input increases, the marginal product decreases, i.e., the total product decreases. In practice, the additional physician (variable input) may not increase, or even decrease, the total product. In the ED, product is defined as efficient patient evaluation and treatment. This will manifest as shorter patient waiting periods in the ED, or lower LOS in the ED. This happens because other staff may be insufficient for the workload or the facility may be overcrowded, so that more staff will only increase pressure and inefficiency.

Patient LOS in the morning shift served as the study control. The observation that patient LOS remained constant during the intervention period supports our conclusion that the change in the medical staff is probably the major factor contributing to the shortening of length of stay. However, our model bears several limitations. The first is that the production function was based on a given, constant level of all other production factors (inputs), such as nurses, administrative staff, and laboratory and imaging services. Using the morning shift as a control probably neutralized much of the bias related to other possible changes in staff efficiency during the study period. However, services provided by the ED, such as administrative, laboratory and imaging, may have been more readily available during the morning shift. The second limitation is that the patient volumes for which a maximal effect of additional medical staff was achieved could be unique to the Sheba Medical Center ED. Thirdly, the staff to patient ratio and the patient case-mix are likely to vary from one ED to another. It should also be remembered that the decrease in average LOS, though statistically significant, was of a small absolute magnitude. Therefore, cost-benefit considerations should be determined for every ED. Nevertheless, the finding that certain patient volumes (i.e., intermediate crowding) for which adding a physician is most efficient may be used as a basis for improving staff allocation in other EDs.

In summary, our study demonstrated that for specific patient volumes, an additional physician can have a significant positive effect on the average patient length of stay in the emergency department. An additional positive effect is the significant decrease in the proportion of patients staying for very long periods, and accordingly an increase in patient satisfaction. This study presents a tool that may be used by ED managers to improve medical staffing in the ED according to changing patient volumes. This flexibility is essential in a setting such as the emergency department, which

functions in an unpredictable environment and a stressful atmosphere. Our model also demonstrates the validity of implementing the management by constraint theory in the healthcare system, where identification of bottlenecks may allow the manager to improve efficacy by concentrating on the most critical factors.

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